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Just Green Iguanas?

The Associated Costs and Policy Implications of Exotic Invasive Wildlife in South Florida

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Invasive exotic species have begun to emerge as a policy issue at the federal, state, and local levels. Although invasive species are often understood as a function of the damage they cause to localized ecosystems, this study diverges by discussing the infrastructural damage caused by an invasive exotic species, the green iguana (*Iguana iguana*). Specifically, the authors discuss the magnitude and scope of damage caused by iguana burrows on canals in southern Florida and offer policy recommendations to move discussions of this potentially disastrous public works issue forward.

Keywords: *invasive species; public works policy; infrastructure; green iguana*

Currently, there is some general interest in the impacts invasive exotic species have on wildlife, ecosystems, and agriculture. Interest in the topic tends to vary across environments and is often driven by some sort of media attention given to a specific problem. This is not limited, however, as it extends to discussions of marine wildlife (Costello, Drake, & Lodge, 2007; Firestone & Corbett, 2005), terrestrial wildlife (Conover, 2001), pathogens (Bright, 1999), insects (Rynk, 2003a, 2003b), and plants (Schmitz & Simberloff, 1997). In each case, the focus tends to be on how these plants and animals can severely damage ecosystems, agriculture, and other areas.

This problem is pervasive. The Great Lakes and associated waterways have been affected by zebra mussels (*Dreissena polymorpha*; Macisaac, 1996), and parts of California have been affected by exotic plants (Randall & Hoshovsky, 2000). Most people in the southern and southwestern United States are familiar with the issues that emerge from insect infestations such as those of red fire ants (*Solenopsis invicta*). Rangelands and pastures are also at risk from diffuse knapweed (*Centaurea diffusa*), which is nearly a ubiquitous weed (DiTomaso, 2000). Although these invasive species problems exist throughout the United States, Florida has been identified as one of the two states with the most severe invasive species problems (U.S. Congress, Office of Technology Assessment, 1993).

Recently, this problem has changed to begin including issues such as conflicts with humans and human habitation, but little has been done to examine the damage these invasive exotics have on infrastructure. The systematic damage these invasive exotic species cause has emerged as an issue of interest (Conover, 2001; Meshaka, Butterfield, & Hauge, 2004). Until now, these damage valuation studies have focused on broad economic costs and framing the scope of the problem (Pimentel, Lach, Zuniga, & Morrison, 2000) or on damage caused by some single species of animal, such as feral swine (Engeman, Shwiff, Smith, Constantin, 2004; Engeman et al., 2004). Unfortunately, not enough attention has been given to the broader consequences of damage by invasive species to humans in general and to their impact on infrastructure in particular.

To remedy this gap in the literature, we focus specifically on the infrastructure damage caused by the green iguana (*Iguana iguana*) in southern Florida. This animal, unlike many exotic invasive species, is sometimes seen as nonthreatening and is sometimes even nurtured in urban areas (Meshaka, Bartlett, & Smith, 2004). With few natural predators, these creatures have become very successful, giving rise to certain public works and policy issues.

Specifically, green iguana populations have increased dramatically in the past 2 years along canals and levees in and around the "greater Everglades" (Ferriter et al., 2007, p. 9-45), along with growing numbers of burrows that can at the very least "present a maintenance liability to surface water infrastructure," if not a substantial danger to residents. Currently, areas affected by burrowing include the C-7, C-111, C-11, and C-1 west canals, leading to both instability and bank erosion.

As a means to better understand the magnitude of the problem, it is important to also understand the frequency and scope of these burrows. Ferriter et al. (2007) offered a preliminary report to the South Florida Water Management District and the National Park Service. The burrows in the study ranged between 0.3 and 2.4 m deep, with a diameter of 10 to 20 cm. Burrow densities are not reported in Ferriter et al.'s report. Consequently, we sought to determine these densities, leading us to collect burrow data from the C-1, C-11, and C-111 canals (Figure 1).[1] The summary information is reported in Table 1.

Using the C-11 canal sample area (the least dense) as a basis, we found a burrow density of approximately 1 burrow for every 60 ft^2 (Sementelli, Smith, Meshaka, & Alexander, in press). This more serious finding is supported by Smith, Engeman, et al.'s (2007) study, in which 45 burrows were found along a 396-m transect undermining an Intracoastal Waterway cement seawall, with 17 of the burrows located along a single 96-m section. The scope of damage at these various sites has been seen as both unexpected and compelling. Currently, the Florida Invasive Animal Task Team is evaluating the green iguana as a problematic, nonnative reptilian species causing adverse environmental effects.

It has become apparent that that the unchecked propagation of green iguanas will further affect Florida's infrastructure and ecosystems by potentially reducing the effectiveness of flood management systems, while competing successfully with a number of native species for niche spaces, habitat, and dominance (Mckie, Hammond, Smith, & Meshaka, 2005; Meshaka, Bartlett, & Smith, 2004; Meshaka, Butterfield, et al., 2004; Smith, Golden, & Meshaka, 2007; Smith et al., 2006; Smith, Meshaka, Golden, & Cowan, 2007). Collectively, these two issues raise concerns about both the biotic and the abiotic environment in southern Florida. This in turn creates an opportunity to reconsider the policy options and implications

Figure 1
C1, C11, and C111 Canals: Focus on Broward County and Miami-Dade County, Southern Florida

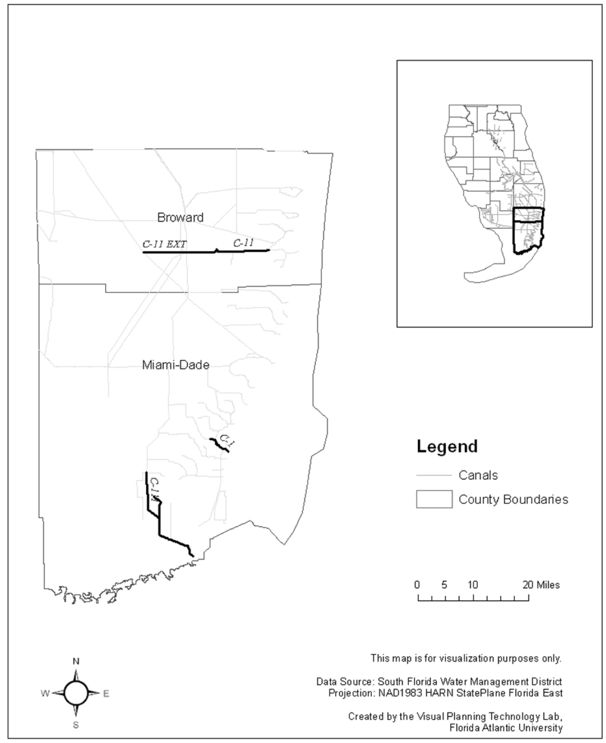

Table 1
Burrow Density Data for the C-1, C-11, and C-111 Canals

Location	Burrows	Sample Area (ft^2)	Estimated Density (per hectare)
C-1	14	800	1,883
C-11	60	3,600	1,740
C-111	21	800	2,825

opened by discussions of green iguanas and other exotic invasive species.

Population Density Issues

As of June 2007, the green iguana had become a widely distributed, well-established exotic species in southern Florida (Meshaka, 2006; Meshaka, Bartlett, & Smith, 2004; Meshaka, Butterfield, et al., 2004; Smith, Golden, et al. 2007; Smith et al., 2006; Smith, Meshaka, Golden, et al., 2007). It has consistently expanded its geographic range (Meshaka, Bartlett, & Smith, 2004) and is capable of reaching extreme population densities (up to 626.6 iguanas/km^2), even in managed natural areas (Smith, Golden, et al., 2007; Smith et al., 2006). These colonies have become such an intrusive problem (Meshaka, Bartlett, & Smith, 2004; Smith, Golden, et al. 2007; Smith et al., 2006; Smith, Meshaka, Golden, & Smith, 2007) that current policies and practices must be reconsidered.

To be successful, we argue this reconsideration must be holistic, considering both the biotic (Smith, Golden, et al., 2007) and abiotic issues, though to date, the biotic issues have received far more attention relative to the abiotic (particularly infrastructural) issues. We know that limiting factors, such as habitat types (Meshaka, Bartlett, & Smith, 2004; Townsend, Krysko, & Enge, 2003), mammalian predators (Meshaka et al., 2007; Smith et al., 2006, Smith, Meshaka, Busch, & Cowan, 2007), and colonization patterns (McKie et al., 2005; Meshaka, Bartlett, & Smith, 2004; Smith, Golden, et al., 2007), have been identified in the literature.

It is also clear that green iguanas are not as successful when sharing habitats and niches with trophic competition from midlevel mammalian carnivores, such as raccoons (*Procyon lotor*) and gray foxes (*Urocyon cinereoargenteus*). Specifically, in the case of Hugh Taylor Birch State Park, it was found that the green iguana population increased 2 to 3 years following the removal of 160 raccoons in November 2000 (Smith et al., 2006). This suggests that raccoons limit the green iguana population size in southern Florida (Meshaka et al., 2007; Smith et al., 2006).

There is substantial corroborating evidence for this phenomenon of raccoon depredation. The predation of iguana nests by raccoons has previously been reported for Florida by Kern (2004, p. 6), as well as for black spinytail iguana (*Ctenosaura similis*) nests in Belize (Platt, Meerman, & Rainwater, 1999; Platt, Rainwater, Miller, & Miller, 2000, p. 167). Predation of hatchling, juvenile, and adult iguanas of various species by raccoons also has been well documented in the biological literature (Cohn, 1989; Fry, 2001; Kern, 2004; Smith et al., 2006; West Indian Iguana Specialist Group, 1999). One might then argue that the predation of nests is a pivotal mechanism for the suppression of green iguana populations in Florida by raccoons (Meshaka et al., 2007).

Likewise, it is apparent that iguanas were severely affected by mammalian predators in Belize. Meerman (1996) reported an insular population of only large adults, arguably the result of predation by rats (*Rattus spp*.). On a nearby atoll, where rats were present but not numerous, the size-class distribution of black spinytail iguanas was normal (Platt et al., 1999). It was also reported by Platt et al. (1999) that raccoons were a major nest predator of black spinytail iguanas.

A similar phenomenon occurred at Cape Florida State Park. After the removal of 97 nuisance raccoons in 2001 and 165 in 2002, the peak density of green iguanas in the park rose to 626.6 iguanas/km^2 (Smith, Golden, et al., 2007) after 2 years. Additionally, the peak number of road-killed green iguanas also rose, constituting more than 30% of all road kills for the entire study period at the park (Smith, Meshaka, Golden, et al., 2007).

It is important to note that these bursts in green iguana populations happen quickly for documented reasons. First, they mature quickly; male green iguanas at our study sites are sexually mature within about 20 months and females at about 31 months (Meshaka et al., 2007). Second, they produce clutch sizes up to 49 eggs in Florida (Meshaka, Butterfield, et al., 2004). Third, the species also can be long lived, between 15 and 20 years. This leaves us with an invasive species that has the potential to rapidly flood any suitable habitat with large cohorts of juveniles. This problem becomes particularly apparent in the absence of mammalian predators and niche competitors, equating to easy colonization and range expansion.

Biotic Damage and Dispersal Issues

Iguanas have been observed affecting a number of imperiled species, such as the Florida burrowing owl (*Athene cunicularia floridana*; McKie et al., 2005), by usurping burrows. Each lost owl, under the Florida Wildlife Code (Florida Administrative Code 39), has an associated cost of $500. Green iguanas have been observed using gopher tortoise (*Gopherus polyphemus*) burrows (without cohabitating), illustrating another potential impact. There is some evidence to support green iguana depredation of egret eggs as well (Arendt, 1986). Each egret, like the Florida burrowing owl, carries with it an associated cost of $500 per incident, per the Florida Wildlife Code.

Green iguanas also cause plant community damage. According to an ongoing study in Florida state parks, green iguanas have been identified as dispersal agents. Specifically, they tend to consume the fruits of invasive plants and deposit seeds throughout their home range (HTS, personal observation; Stacey R. Sekscienski et al., unpublished data). The primary consequence of this is the expansion and distribution of invasive plants that mirrors the expansion and distribution of iguana populations.

These biotic issues are exacerbated by inadequate penalties for releasing green iguanas into southern Florida's ecosystem. Currently, the release of green iguanas is considered a first-degree misdemeanor (according to Florida Statute 372.265[3]), with an additional civil penalty of $500 (imposed under Florida Administrative

Code 39-4.005). However, as always, enforcement could be improved with additional resources. From the biotic damage and dispersal issues alone, the cost of these iguanas drastically outstrips the current fine structure, illustrating a disconnect between policy and practices.

Transportation and Infrastructure Issues

The most pressing issues beyond those of niche space competition, predation, and dispersal are infrastructure related. As stated earlier, green iguanas have been observed burrowing in canals, levees, and dikes and along seawalls in southern Florida. There is additional evidence that these animals have begun to inhabit basic traffic and air corridors (HTS and WEM, personal observations). Specifically, iguanas may also become airplane collision hazards on airport runways at the Homestead Air Reserve Base, and other airports around Miami and Tampa, as they have in Puerto Rico (Engeman, Smith, & Constantin, 2005).

It is important to realize the magnitude of damage these lizards can cause to canals, levees, and dikes. Burrowing animals should not be overlooked as facilitators of hydraulic structure failure (California Department of Water Resources, 2005; Federal Emergency Management Agency, 1999; Hegdal & Harbour, 1991): "Prudent managers should bear in mind that failure to control potentially threatening animal activity could ultimately result in major canal breaks or loss of earthen dams (with concomitant law suits and damages running into the millions of dollars" (Hegdal & Harbour, 1991, p. 1). Breaches in hydraulic structures can flood urban and agricultural sites, destroy aquaculture, contaminate drinking water, facilitate the spread of invasive plants and animals, mix freshwater and saltwater, and disperse hazardous waste. For example, after the Linda Levee near Marysville, California, broke during a flood and caused extensive damage to agricultural and urban areas, litigation continued for years. Courts ruled in favor of the plaintiffs against the state, resulting in a claim of more than $1 billion (including interest but not litigation costs). The specific cause of the breach was not determined, but burrowing animals figured prominently in the case. Another event, not associated with a storm, occurred when 11,000 acres of farmland near Stockton, California, were flooded from a breach in the Jones Tract Levee, causing $22 million in damage (County of San Joaquin, Office of Emergency Services, 2004). Burrowing animals were again suspected as the facilitators of the breach.

The highest currently reported green iguana density of 626.6 iguanas/km^2 in Florida (Smith, Golden, et al., 2007) equates to a minimum of 6.2 burrows/hectare, assuming that each animal digs a burrow. Consider that these burrows have been measured to be as much as 2 m (roughly 6 ft) deep and as much as 20 cm (7.8 in) in diameter. Consider that a simple commercial pond access levee is roughly 20 ft wide (Steeby & Avery, 2002). The iguana burrows could reasonably penetrate 30% of the levee structure, making the levee 14 ft in diameter for practical purposes. Add to this the information that even small amounts of erosion can render levees narrower than 16 ft unusable in less than 5 years (Steeby & Avery, 2002, p. 2), and one can begin to understand the scope of the problem. Furthermore, if we reconsider the data in Table 1, reporting densities of 1,740, 1,883, and 2,825 burrows/hectare from the surveyed sites, the problem becomes alarming.

Anecdotally, throughout southern Florida, burrows have begun appearing in other areas, including canals, levees, and dikes used for flood control and water management. It is therefore plausible that burrows such as those could similarly damage these other structures within a short time frame, unless steps are taken to repair and maintain them. On the basis of focus group discussions with service directors, civil engineers, construction professionals, and water managers, the estimated cost to properly repair each hole was estimated to be approximately $400. Taken as a group, with a minimum of 6.2 burrows/hectare, these repair costs come to $2,480/hectare. Additionally, because it takes an iguana only roughly 2 to 3 days to construct a new burrow, unless appropriate action is taken, these maintenance and repair costs could be encumbered conservatively on a quarterly basis simply to maintain the current integrity of these structures.

Policy Recommendations

The nature of this exotic invasive species and the associated perceptions of it create certain issues for the community. No single policy option proposed in this piece will by itself adequately address the problem at hand. Instead, policy makers, managers, and other public officials should consider combinations of these options to present a more comprehensive approach to this problem. There are also certain geographic, cultural, and perceptual issues that serve to either limit or move items along policy agendas. To this end, we have proposed a number of short-, medium-, and long-term options for consideration, and we note the limitations of each.

Short-Term Recommendations

It is important to note that a majority of the green iguanas observed in urban park settings are effectively "landlocked" (i.e., surrounded by urban infrastructure). This makes trapping and removal a desirable short-term solution, ideally using licensed wildlife control operators. Drawbacks of this option include protestation by area residents who have "adopted" these animals (Meshaka, Bartlett, & Smith, 2004), by certain animal protection groups, and by others. Some might also advocate for a bounty system, but the opening of trapping and removal through a bounty system in the state could have a number of undesirable consequences, including but not limited to the possible unlawful discharge of firearms within city limits; potential injuries to citizens, pets, and other wildlife; and injuries due to the improper handling of captive animals. However well intentioned, this option might also encourage sustainable harvesting rather than elimination.

As stated earlier, there has also been some discussion regarding what to do to the damaged canals, dikes, and levees. With an estimated repair cost of roughly $400/burrow, it would be useful to offer solutions that would last longer than the 2 to 3 days it takes an iguana to construct a burrow. Focus groups with local experts, including a number of engineering and construction firms, uncovered a practical solution that could be implemented in the short term. Using existing technology, it is possible to fill existing holes with concrete, cover the damaged banks with wire mesh, and finally blow in approximately 2 in of concrete to better seal the areas in question. This solution could reduce or prevent further damage, with a cost of approximately $600 to repair an area 10 by 16 ft.

The focus groups used in this study considered a number of strategies to repair and remediate the damaged areas. The most desirable would be to reinforce the compromised dams, levees, and seawalls with wire mesh and use blow-in concrete to fill the holes and stabilize the overall structural integrity of the infrastructure in question. Other solutions considered included simply filling the holes with existing soils, filling the holes with a combination of soil and cement as well as other soil-mixing strategies, and planting. These other options were ultimately excluded by the focus groups given the scope of damage, the long-term viability of the solutions proposed, and the feasibility of implementation.

From a public works standpoint, this policy option has other benefits. These benefits include helping make these primarily earthen constructions more resistant to damage from storm events, flood situations, and even normal wear. From a cost standpoint, it appears at least initially to be a better use of resources than either simply filling the holes or other options.

A major drawback of this solution would be the potential loss of habitat for other species currently occupying the same area such as Florida burrowing owls and gopher tortoises.

Medium-Term Recommendations

Medium term solutions include the education of residents, citizens, and local government officials on the short- and long-term impacts of these green iguanas on the infrastructure, on the habitats, and on endangered and protected species in southern Florida. The awareness and education program would have a component to encourage people to not harbor these animals or introduce them into ecosystems and would provide information regarding the sorts of fines and problems incurred by such actions. This educational program, to be effective, should be paired with proposed changes in rule making that would help bring current fine structures in line with the associated costs of damage.

Specifically, policy makers may consider some form of taxation as a mechanism to absorb or recover at least part of the damage done by green iguanas, similar to what was proposed by Jones and Corona (2008), such as at some point of introduction. Although they focused on addressing taxation of invasive species introduced in port waterways, their logic could be used to develop a similar strategy for terrestrial invasive species. At a minimum, the tax or fee should enable the state to recover some of the costs of infrastructure repair and the cost of damage to native ecosystems as well as offset some expenses incurred through added enforcement.

Long-Term Recommendations

In the long term, senior wildlife biologists at the U.S. Department of Agriculture's National Wildlife Research Center and the Florida Park Service have shown interest in pairing a baiting and sterilization program (M. L. Avery, National Wildlife Research Center, personal communication, May 31, 2007) with the removal of colonial nesting sites where green iguanas congregate when nesting sites are limited (Meshaka et al., 2007). In this combined approach, the goal is to curtail recruitment by the removal of eggs and simultaneously by the sterilization of adults.

The attractiveness of this approach is that it reduces the perception of hostile trapping and removal programs from the public eye, a concern not to be discounted in light of the relationship that many south Florida residents have with this exotic species (Meshaka, Bartlett, & Smith, 2004), especially in urban, high-visitation, public trust lands where the species is considered endearing by park visitors (HTS and WEM, personal observations). However, the efficacy of sterilization is unknown for this species in

Florida, and even in a best-case scenario, it extends the effects of green iguanas on the southern Florida environment, wildlife, and public works for 10 to 20 years as populations atrophy naturally. This relatively "invisible" approach would be challenged by its time frame for success, its expense, and the current state of the science in the face of a geographically expanding and ecologically deleterious exotic species. Notwithstanding sensitivity to positive cultural attitudes toward feral green iguanas in some areas, sterilization brings with it monetary expense and long-term negative effects on the ecosystem more than the immediate euthanizing of captured animals.

Consideration might also be given to the option of banning the private ownership in Florida of this demonstratively invasive and deleterious species. Presumably, a public informed of the negative effects of this species on other species and public works structures, which affect human health and safety, would value this option. A ban of sale also has the added benefit of increasing the effectiveness of the aforementioned options by eliminating sources of new animals that could escape and extend the process of removal indefinitely.

An integrated approach that works across these three time frames would appear to be the most useful. One might consider the advantages of limited, regulated removal and repair of the damaged areas combined with a broad-based education and awareness program, along with rule-making changes. Adult animals could be trapped and removed from the population, while juvenile animals could be trapped and sterilized in the short term on a case-by-case basis under the supervision of the appropriate state and federal authorities. Juvenile lizards, once sterilized and chipped, could be distributed through animal shelters for a nominal fee. The resale of these sterilized juvenile animals as pets outside Florida might help depress the value of the lizards as pets, enhance the tracking of animals released after sale, and offset some of the costs of the program. This option also helps discourage the importation of unsterilized animals into the state by reducing the profit margin on each animal. When combined with a medium-term education program, this multifaceted approach could be effective.

Conclusions

Invasive exotic species have created serious problems throughout the United States. Although a great deal of research has been conducted on the associated costs and policy consequences of plant invaders, wildlife studies have been far less prevalent. In the case of green iguanas, these creatures have impacts on urban life, on ecosystems, and on public works infrastructures. Despite the green iguana's having been identified as a target species for concern, much remains to be done concerning a systematic, comprehensive approach to the management of this species in southern Florida, as well as careful management of the damage it causes, in this case to public works structures.

It is fundamentally important for state policy makers, public trust land managers, and local government officials to understand the costs associated with these animals. Our conservative discussion of damage to flora and fauna, along with the associated maintenance and repair costs these creatures incur, identifies specific areas and opportunities for reform as well as agency rule making. In general, the associated costs of this highly successful, exotic species should move it forward on policy agendas.

Without education and training, citizens and some policy makers might be tempted to dismiss this issue as being "just green iguanas," without fully appreciating the biological and infrastructural effects these creatures have both on our urban infrastructure systems and on our ecosystems. Additionally, if one considers the increased frequency of storms and flooding across the United States in recent years, we cannot afford to ignore the damage caused to our water and flood management systems.

Note

1. This information was collected on two separate occasions. The initial information came from Sementelli et al.'s (in press) article. The information on the C-1 and C-111 canals was collected in cooperation with Coast to Coast, Inc., on August 4, 2007.

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